—Proposal—
Wapato Lake Water Management Planning Study

Prepared by

Norman L. Buccola, Micelis Doyle, Jami Goldman, and Stewart A. Rounds
U.S. Geological Survey
Oregon Water Science Center
2130 SW 5th Avenue
Portland, OR 97201
nbuccola@usgs.gov, mcdoyle@usgs.gov, jgoldman@usgs.gov, sarounds@usgs.gov,
503-251-3245, 503-251-3226, 503-251-3205, 503-251-3280

Summary

The U.S. Fish and Wildlife Service (USFWS) recently acquired a majority of the Wapato Lake Bed and surrounding land located in Washington and Yamhill Counties, Oregon with plans to protect and restore roughly 4,310 acres of fish and wildlife habitat in the area (figure 1). The USFWS is currently in the process of developing a Comprehensive Conservation Plan (CCP) to manage this land referred to as the Wapato Lake Unit (WLU) of the Tualatin River National Wildlife Refuge (TRNWR). The CCP being developed for the TRNWR is intended to guide management of the WLU for the next 15 years (USFWS, 2010). The USFWS has expressed interest in having the U.S. Geological Survey Oregon Water Science Center (ORWSC) assist in this effort by conducting a hydrologic and water quality study of the WLU subbasin. Findings from the study will help address some of the potential challenges facing the future water management and restoration efforts within the WLU. Particular needs that have been identified by the USFWS include:

- The need for an accurate 3-dimensional representation of the topography and bathymetry of the Wapato Lake area,
- The need for an estimated water budget: accounting for water inputs and outputs to and from the lake, including surface and groundwater flows, precipitation, and evaporation, and
- The need to understand the existing and potential future water quality of the lake under various restoration options (including the removal of dikes/levees and water-level management).

Water management of the proposed Wapato Lake Unit will directly affect water quality in the lake as well as downstream in the Tualatin River for the major drinking water provider (Joint Water Commission [JWC]), irrigation water provider (Tualatin Valley Irrigation District [TVID]), wastewater/stormwater managers (Clean Water Services), and aquatic ecosystem health. The goal of this proposal is to recommend and outline a set of activities related to scientific monitoring, streamflow and water quality modeling, and analysis that the ORWSC could undertake to help inform those who are concerned with water management and water quality in Wapato Lake and downstream in the Tualatin River.

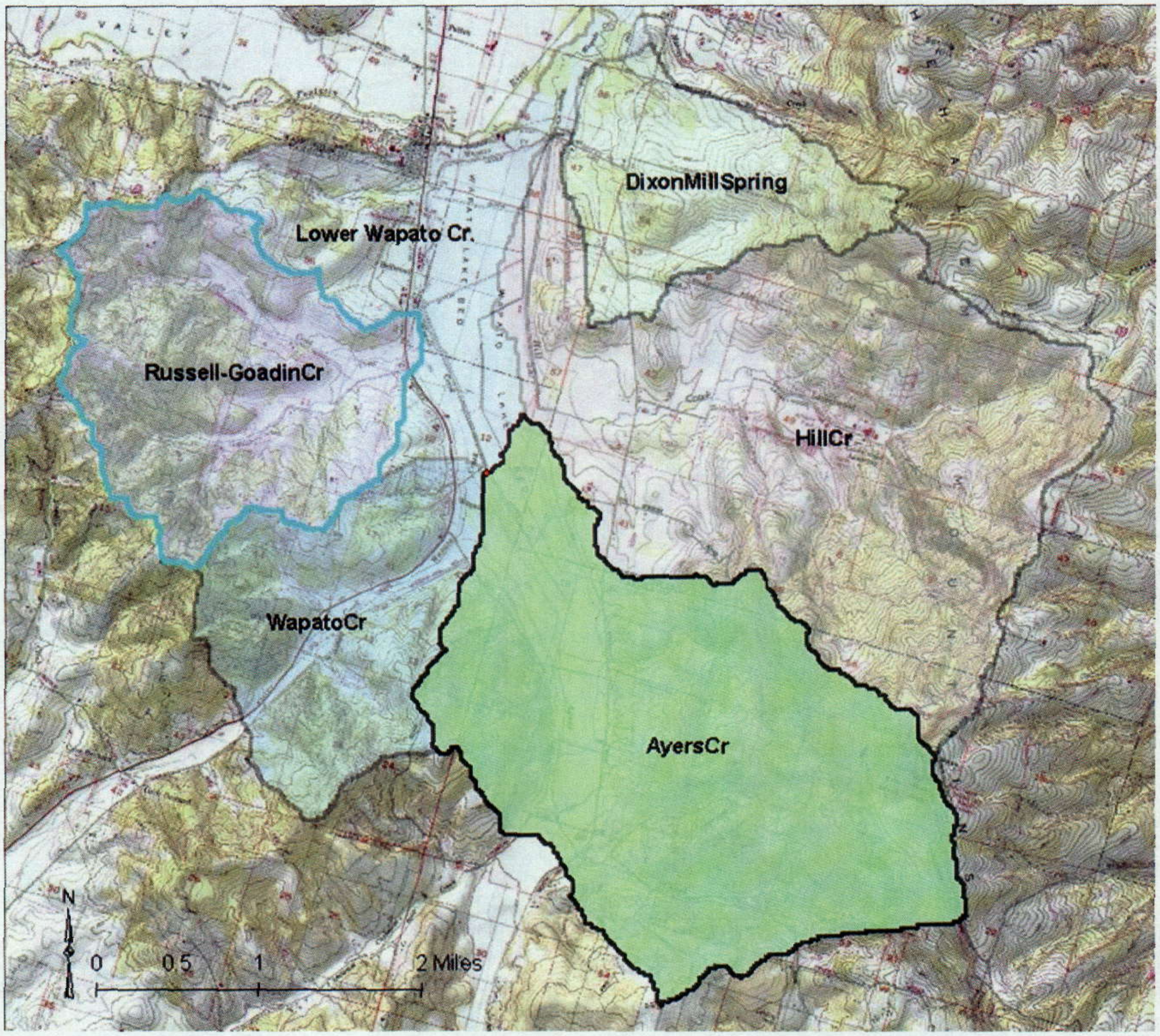
Background

Prior to the 1930s, seasonal high flows in the upper Tualatin River filled the lowland area comprising Wapato Lake. The Wapato Improvement District (WID) was formed in the mid 1930s to manage the Wapato Lake Bed for agricultural purposes, and a network of dikes and canals were constructed to minimize the seasonal flooding and convey water during summer to various tracts of farmland in and around the lake bed. Prior to the growing season, water in the lake was pumped out to allow farmers to cultivate the land. To augment tributary inflows during the summer dry season, a diversion canal from the Tualatin River to the Wapato Lake canal system was constructed to route water around the lake to surrounding agricultural lands. Since the construction of the levees, streams that previously flowed into Wapato Lake no longer do so, leaving rainfall, groundwater seepage, and leakage through the dikes as the only hydrologic inputs to the lake bed during the summer growing season.

Water Storage Impacts

Under "Alternative D" of the proposed USFWS restoration plan, 4,310 acres in the Wapato Lake area would be acquired (USFWS, 2007). Water rights used by TVID and the WID would be applied and used to restore seasonal fall and winter flooding of wetlands in the Wapato Lake Bed (USFWS, 2007). The existing lake is estimated to have a volume of about 5,000 acre-feet at full pool (Dummer, 2010). If the lake was managed as a "run-of-river" inundated area, some of this additional water storage could augment existing storage capacity for downstream water providers such as TVID and JWC, but only if the quality of that water is acceptable for downstream uses. TVID and JWC have rights to remove water from the Tualatin River at the Springhill Pump Plant about 2 river miles downstream of the confluence of Wapato Canal with the river; these organizations withdraw a substantial quantity of water—approximately 96.4 and 85 cubic feet per second during the summer of 2009, respectively (Tualatin River Flow Management Technical Committee, 2010). The management of inflows and outflows to and from the WLU will directly affect downstream water quality in the Tualatin River, thereby affecting withdrawal and flow augmentation practices conducted by JWC and Clean Water Services.

Figure 1. Map of the Wapato Lake Unit subbasin drainage areas.



Potential Water Management Issues

As the existing lowland area of Wapato Lake is likely to be inundated under future management scenarios, it is important to understand the potential implications this may have for in-lake water quality. Water quality issues associated with restored wetlands and shallow lakes may include potential anoxic zones, high pH during times of high algal productivity, and the potential presence of algal toxins. Additionally, residues from historical use of pesticides in the basin may be of concern for healthy aquatic and avian habitat in the restored WLU. The USGS seeks to provide a better understanding of some of these potential issues as they relate to the future management of Wapato Lake.

Drainage from Wapato Lake enters the Tualatin River from the Wapato Lake outlet canal (referred to as Wapato Canal in this proposal) and has historically resulted in decreased water quality downstream (Tualatin River Flow Management Technical Committee, 2009). For example, a breach in the dike on the west side of the lake bed in December 2007 allowed the lake bed to flood to a much greater extent than normal. Due to the dike breach, the WID was unable to begin dewatering the lake until the water level receded in June 2008 and was not pumped dry until July 2008 (WID, 2009). In the summer of 2008, elevated blue-green algae and zooplankton levels were observed in the Tualatin River concurrent with the greatest discharge rates from Wapato Lake (Tualatin River Flow Management Technical Committee, 2009). During this time, both Clean Water Services and JWC increased their releases from Barney Reservoir and Hagg Lake to dilute the Wapato water releases and mitigate the various water quality problems. JWC also incurred additional and substantial costs while treating taste and odor problems associated with Wapato releases during the summer of 2008 (Dummer, 2010). To help reduce the risk of unexpected costs associated with these water quality problems, a better understanding of the current and future management of the Wapato Lake system will benefit USFWS, JWC, Clean Water Services, and TVID.

Previous Work

During the spring and summer of 2010, a broken water pump at the Wapato Lake pumphouse near the SW Gaston Road bridge prompted a request from Clean Water Services for USGS to monitor certain water quality parameters in the Wapato canal downstream of the lake. These efforts resulted in 3 months of continuous records of temperature, conductivity, pH, turbidity, dissolved oxygen, total chlorophyll, and blue-green algae data. Additionally, there were grab samples collected and analyzed for algal species classification. These data will provide a foundation for assessing the potential range of future environmental conditions and may help guide management strategies for the WLU.

Objectives

This proposal outlines actions that are among the most pressing water-related information needs of resource managers for the Wapato Lake area of the Tualatin River basin:

1) Create a detailed digital elevation model (DEM) of Wapato Lake and the surrounding area using topographic survey data and LiDAR to quantify a lake stage-to-volume relation.
2) Develop a water balance model for the Wapato Lake area based on measurements and estimates of inflows, outflows, and potential water levels in the lake.
3) Construct a nutrient/algal model that will predict nutrient and algal-phytoplankton dynamics in the Wapato Lake system and the quality of water exported downstream to the Tualatin River.

4) Provide continuous monitoring of water quality and meteorology of the Wapato Lake Unit initially for two growing seasons.

Approach

A wide range of data is required to evaluate water quality conditions and support analytical modeling of the Wapato Lake area. A digital elevation model (DEM) of the existing terrain as well as the presumed terrain under restoration scenarios of interest is necessary to quantify the volume of water that is held in the lake under various water-management strategies. Flow data, including inflows, diversions, and stage data, are required to estimate the water budget and determine hydrodynamic controls on water quality. Water temperature and water quality data collected at multiple locations will enable the assessment of spatial and temporal variations in water quality conditions. Meteorological observations including precipitation, air temperature, wind velocity, humidity, and solar radiation are necessary to compute a heat budget for the lake and quantify wind-mixing processes. Experimental work is proposed to focus on understanding the quantity and status of algae, characteristics of organic matter, and bacterial processes that may occur if/when inundated lake bed conditions exist during the summer. The combination of field data and experimental results will be used to formulate a conceptual model, evaluate the use of an existing model, and aid in construction of the most appropriate model to evaluate management scenarios with the goal of improving water quality in the lake and in the outflow to the Tualatin River.

Objective 1) Create a detailed digital elevation model (DEM) of Wapato Lake and the surrounding area using topographic survey data and LiDAR to quantify a lake stage-to-volume relation.

The creation of an accurate DEM of the Wapato Unit lake bed and surrounding area is the primary step in quantifying a stage-volume relationship and building a framework for water management. A bathymetric DEM (grid) of the lake will be created through GIS analysis of LiDAR, and field surveying measurements. The most current LiDAR dataset was collected in June, 2007 during a time when Wapato Lake was mostly inundated; those data, therefore, are not sufficient for building an accurate stage-volume relationship. A new LiDAR dataset flown during the dry season would provide topographic data for this missing area. To validate any LiDAR dataset, a field survey of the dry lake bed using the latest surveying equipment is necessary. While LiDAR data may not be available until 2012, a field survey of the dry lake bed during the summer of 2011 will enable a GIS integration of the 2007 LiDAR with bathymetric survey data to begin as soon as possible, leading to a sufficiently accurate DEM representation of the entire Wapato Lakebed. This will provide vital information for planning processes related to water storage in Wapato Lake to proceed as soon as possible (before the summer of 2012). Once the DEM has been constructed, alternative DEMs would be created to represent the bathymetry of hypothetical scenarios such as breaches in the dike system or pre-dike topography. These DEMs could then be used to measure inundation areas suitable for aquatic habitat, as well as input later into a water quality model that could compare the effects of potential management strategies.

After an updated LiDAR dataset is gathered (potentially as soon as the summer of 2012), existing DEMs that have been created will be updated/verified for their completeness and level of accuracy. LiDAR provides additional resolution and detail that will augment the topographic field survey dataset.

Objective 1 Costs	Partnering with USFWS		Partnering with State/Local Agency		Subtasks
Federal Fiscal Year	Funds from Collaborator	Funds from USGS	Funds from Collaborator	Funds from USGS	
2011	$26,850	$0	$16,800	$11,200	Topographic survey, GIS processing
2012	$49,050	$0	$30,650	$20,450	LiDAR, GIS processing
Total	$75,900	$0	$47,450	$31,650	

Costs in federal fiscal year (FY) 2012 may be reduced by collecting LiDAR datasets in conjunction with a LiDAR flight already planned by a partnering agency. Costs in FY 2012 can be further reduced by not gathering a new LiDAR dataset. Topographic survey costs in FY 2011 may also be reduced if a partnering agency takes on this work. GIS analysis would proceed with information shared by partnering agencies to insure that methods are consistent.

Objective 2) Develop a water balance model for the Wapato Lake area based on measurements and estimates of inflows, outflows, and potential water levels in the lake.

In order to manage the water in the lake, the hydrologic inputs (Tualatin River canal diversion, tributary streamflow, precipitation, groundwater seepage) and outputs (Wapato Canal exports, irrigation deliveries, evaporation, groundwater recharge, and possibly pumping) must first be assessed. Although diverted inflows from the Tualatin River account for a large portion of the summertime inflow to the lake and canal system for irrigation, seasonal overland inflows in the Wapato Creek subbasin will need to be measured.

Estimating Ungaged Tributary Streamflow

Due to the lack of streamflow data in the subbasin, streamflow discharge measurements under a range of flow conditions are needed to estimate inflow from each of the small tributaries to the lake. A basin-area-ratio approach also can be used to estimate streamflow at ungaged sites using measured streamflow from a gaged stream in a similar basin nearby, but such estimates would need to be verified with some measurements. For example, the streamflow from the East Fork Dairy Creek site (USGS station 14205400) could be proportional (based on respective drainage area) to the daily streamflow in Ayers, Wapato, or Hill Creeks in the Wapato Lake subbasin (Figure 1). Streamflows estimated using this method could then be compared with measured streamflows and refined/adjusted as necessary. To assess the validity of the basin-area-ratio estimation method for ungaged tributary streamflow, discharge will be measured at Wapato, Ayers, and Hill Creeks during low, medium, and high flow conditions. These measurements will provide a basis for estimating the flow contributions from smaller tributaries occurring primarily during the wet season in the Wapato Creek subbasin.

A future refinement of the basin-area-ratio streamflow estimation method mentioned above would include a GIS-based rainfall-runoff model. This approach would incorporate information such as topography, land use type, soil characteristics, and meteorological conditions and provide the ability to predict ungaged streamflow at any point in the sub-basin. A rainfall-runoff model would provide a tool for identifying potential groundwater fluxes contributing to the water balance as well as help predict how climate change and future land use changes throughout the Wapato Lake subbasin may affect future streamflow conditions. Data gathered from the streamflow monitoring efforts would be used to calibrate this model and provide an independent validation of the basin-area-ratio estimation approach. The combined results from both estimation methods (basin-area-ratio streamflow estimation and the rainfall-runoff model) would provide a broad foundation for a subsequent water balance analysis.

Water Balance Analysis

A rough estimate of outflow from the Wapato lake system can be computed under low flow conditions through a simple accounting of river flows measured at several streamflow gages upstream and downstream of the Wapato Lake area: Tualatin River at Gaston, OR (*14202510*), Scoggins Creek below Henry Hagg Lake (*14202980*), and Tualatin River near Dilley, OR (*14203500*). By subtracting the sum of the Scoggins and Gaston flows from the Dilley flow, the gross outflow through the Wapato Canal can be estimated. Historical records of inflow through the Tualatin River diversion canal to Wapato Lake, or lake stage data, will provide additional information to this water balance calculation. This simplified estimate relies on the assumption that withdrawals from the TVID Patton Valley Pump Plant on Scoggins Creek are negligible, that inflows from some smaller creeks are negligible, that outflow from Wapato Lake is substantial, and that the Tualatin River stage at the USGS gage near Dilley is not above bank-full conditions (historical overbank conditions have been reported at this site); failure to meet these conditions would add uncertainty to, or break, the analysis. In addition, uncertainty in streamflow measurements at each of these sites adds to the uncertainty in the computed streamflows.

The accuracy of this method of estimating the gross outflow from the Wapato Canal and lake system is highly dependent on the availability or existence of the historical records described above. The accuracy of those historical records and the extent to which the records exist for the inflow from the Tualatin River diversion canal, outflow water deliveries from the Wapato Lake canal system, and Wapato Lake stage data will affect the ultimate utility of this approach. Inflow and outflow data from years in which records exist may be used to establish statistical relationships that would help assess total losses from the system that would ideally be quantified separately (i.e., evaporation, groundwater influences, and irrigation deliveries). This exercise could be applied to the last five years (2006-2010) to capture recent conditions that include the 2008 levee breach and the 2010 pump malfunction events.

The water balance analysis also would include an analysis of the estimated inflows and outflows in a simple spreadsheet model. The estimated inflows from the ungaged tributaries or from the rainfall-runoff model would be used to help account for water movement through the WLU.

Continuous monitoring of streamflow in the Wapato canal (outflow), streamflow in Ayers Creek (inflow) , Wapato Lake stage, and Tualatin River diversion canal stage (inflow). .

Because of the lack of flow data in the Wapato subbasin, improved accuracy of the water balance analysis could be gained by measuring the stage in the Tualatin River diversion canal, inflows from Ayers Creek (the largest subbasin), outflows from the Wapato Canal and Wapato Lake stage. Depending on the management and usage of the lake and canal system, these inputs, outputs, and withdrawals could contribute significantly to the water balance and should be monitored to the extent that is possible. Most importantly, the inflow from the Tualatin River diversion canal will drive the water balance to the canal and lake system during the summer months and should be accurately monitored. Continuous streamflow measurements in Ayers Creek will provide a basis for estimating streamflow in Hill and Wapato Creeks as well as other contributing tributaries. Monitoring of these inflows and outflows to Wapato Lake is a necessary step in creating a more accurate accounting of the water balance and will provide useful data for water management in the future.

Objective 2 Costs	***Partnering with USFWS***		***Partnering with State/Local Agency***		Subtasks
Federal Fiscal Year	Funds from Collaborator	Funds from USGS	Funds from Collaborator	Funds from USGS	
2011	$85,500	$0	$51,300	$34,200	Install and maintain 2 stage monitors + 2 discharge monitors
2012	$95,350	$0	$58,400	$38,950	Operate 2 stage monitors + 2 discharge monitors, discharge measurements, analyze data, develop water balance
2013	$46,250	$0	$28,900	$19,300	Periodic flow measurements, discharge measurements, develop rainfall-runoff model
Total	$227,100	$0	$138,600	$92,450	

These estimates include 2 continuous stage monitors (Tualatin River inflow canal and Wapato Lake stage) and 2 continuous discharge monitors on Wapato Creek outflow canal and Ayers Creek. Reduction in costs could be achieved by reducing the number of monitoring sites.

Objective 3) Construct a nutrient/algae model that will predict nutrient and algal phytoplankton dynamics in the Wapato Lake system and the quality of water exported downstream to the Tualatin River

To better understand the water quality dynamics of a ponded Wapato Lake, including when algal blooms may occur and what the potential water quality exports from Wapato Lake to the Tualatin River may be at any given time, a water quality model of the lake is essential. Further, a model can help resource managers explore the potential effects of restoration or management strategies in order to minimize adverse water quality conditions or potentially improve the water quality immediately downstream of Wapato Lake. Even more important than a model, however, is the collection of data to adequately understand the potential response and variability of the system. To simulate a nutrient balance and eutrophication response, a complex model requires watershed characteristics and a minimum of one full growing season of inflow/outflow hydrology, nutrient concentrations entering the reservoir, and water quality data from the ponded area. The resulting model will provide information on the nutrient/algal dynamics and will demonstrate how changes to the system (breaching or removal of the dikes, water-level management) could affect water quality. The model will help guide future monitoring efforts and can inform management strategies for the area.

Water Quality Sampling

An extensive sampling plan is needed during the first full year of this project to gather the data needed to (1) develop a useful understanding of water quality inputs and patterns, (2) produce a conceptual model of water quality for the subbasin, and (3) begin to develop a useful and robust water quality model for the lake. Sampling is proposed to continue at decreased intervals beyond the first year for refinement and continued calibration of the models as restoration occurs in the system. The proposed sampling regimen includes multiple sites to characterize the inputs into the Wapato lake system, the lake itself (when inundated), and the outflow Wapato Canal. The monitoring and sampling would include:

- Deployment of remote temperature data-loggers at key tributary inputs (Tualatin River diversion and Wapato, Ayers, and Hill Creeks as well as the lake itself)
- Collection of water samples for analysis of nutrients (dissolved and total phosphorus, dissolved ammonia, nitrite plus nitrate, Total Kjeldahl Nitrogen (TKN), dissolved carbon, total particulate nitrogen and carbon), algae (phytoplankton species, community quantification, and chlorophyll *a*), and zooplankton (species and community quantification) in the lake and tributary inputs (Tualatin River, and Wapato, Ayers, and Hill Creeks)
- Collection of field-parameter profiles (dissolved oxygen, specific conductance, turbidity, pH, and temperature) at the Tualatin River diversion canal and near the outflow of the lake (Wapato Canal)

Samples will be collected on a monthly basis with increased frequency during critical times, resulting in a total number of about 85 samples during the first year and about 30 samples during the second year.

Pilot-scale pond experiments

To understand how contact with soil and sediment affects the quality of ponded water in Wapato Lake, experiments will be conducted to measure interactions at the soil-water interface leading to nutrient releases and algal growth. Pilot-scale inundation experiments on-site would provide an ideal basis for understanding and quantifying the potential nutrient and algal dynamics under a variety of wetland restoration regimes. Such experiments may be as simple as keeping a portion of the lake inundated during one year of this project and monitoring the water quality parameters mentioned above. Alternatively, experimental ponds could be constructed for specialized experiments relating water impoundment to nutrient and algal conditions.

Model Construction and Calibration

Following the first year of data collection, work will begin on a conceptual model of water quality for the WLU as well as a numerical one-dimensional water quality model based on the assumption that the lake is a single, well-mixed basin. The conceptual model will identify those processes that control water quality (nutrients, algae, dissolved oxygen, etc.) in the WLU, determine the linkages between nutrients, temperature, sunlight, and algal growth, and begin to quantify how those processes produce certain water quality conditions. Once the conceptual model has been constructed and tested against the available data, a numerical water quality model will be constructed.

The numerical model will include the most important processes affecting water quality in the WLU, as identified from the development of the conceptual model. Reaction rates that drive nutrient sources and sinks within the water quality model will be based on values derived from the scientific literature, measured water quality data obtained in the lake system, and data derived from the proposed experimental pond system (if available). An initial model may assume that nutrients are not a limiting factor for algal growth to occur; later work may test that hypothesis. It will be difficult to construct and calibrate an accurate and predictive numerical water quality model without a good set of field data from the study area, which reinforces the need for experimental algal growth data. The water quality model may need to be constructed and tested in phases over a period of two or more field seasons to gain sufficient predictive certainty, but preliminary results that may be useful for planning purposes should be available by the end of the second year of the project. Initially for the numerical modeling exercise, it will be assumed that phytoplankton (free-floating algae) dynamics will be among the most important processes that affect water quality. As aquatic plant communities begin to recolonize the restored water column in Wapato Lake over time, however, it may become apparent that rooted aquatic plants and epiphytic algae also are important factors that should be considered in the conceptual model.

Objective 3 Costs	***Partnering with USFWS***		***Partnering with State/Local Agency***		Subtasks
Federal Fiscal Year	Funds from Collaborator	Funds from USGS	Funds from Collaborator	Funds from USGS	
2012	\$166,000	\$0	\$103,800	\$69,200	Intensive water quality sampling, pilot-scale pond experiments
2013	\$177,600	\$0	\$111,050	\$74,050	Water quality sampling at selected sites, pilot-scale pond experiments, model construction
Total	\$343,600	\$0	\$214,850	\$143,250	

Cost estimates related to laboratory analysis of nutrients could be reduced by partnering with the Clean Water Services water quality laboratory. Costs could be further reduced if Joint Water Commission water quality sampling schedules and sites overlapped with those determined in this objective. In this case, information and protocols would be shared to insure that data quality and collection methods are identical.

Objective 4) Provide continuous monitoring of water quality and meteorology of the Wapato Lake Unit initially for two growing seasons.

Water Quality Monitoring

Continuously measured water quality data such as temperature, pH, dissolved oxygen, turbidity, total chlorophyll, blue-green algae, and conductivity are essential to understand the daily, seasonal, and annual patterns of water quality in the WLU, and are critical to the development of a dynamic water quality model of Wapato Lake. We recommend that a minimum of one continuous water quality monitor be installed downstream of the outflow of the lake in the Wapato Canal. Having data from this location will provide a valuable calibration check to aid in the construction and accuracy of a water quality model. This would allow a quantification of the outputs from the lake and isolate the effects of water quality processes occurring as management of the lake continues to evolve. This proposal includes the cost of one continuous water quality monitor near the primary outlet of Wapato Lake (Wapato Canal, downstream of the pumphouse). This monitor would be installed in the spring of 2012 and collect data year round for two consecutive years thereafter.

Meteorological Monitoring

Parameters such as solar radiation, wind velocity, air temperature, relative humidity, and precipitation are important in determining the mixing, re-aeration, stratification, and evaporation that occurs within shallow aquatic environments, as well as the available light for algae and plant growth. Although many of these parameters are measured at other locations within about 6 miles of the study area in Verboort, OR (FOGO Agrimet station, Bureau of Reclamation, 2011) and some data (air temperature and precipitation) are collected about 4 miles away in Dilley, OR by the Oregon Climate

Service, neither of these sites are directly on the premises of Wapato Lake and therefore may not be representative of the micro-climate in the immediately vicinity of the lake. Therefore, it is proposed that continuous monitoring of these meteorological parameters be collected near the Wapato Lake pumphouse (Gaston Road bridge) during the growing season for three consecutive years.

Objective 4 Costs	***Partnering with USFWS***		***Partnering with State/Local Agency***		Subtasks
Federal Fiscal Year	Funds from Collaborator	Funds from USGS	Funds from Collaborator	Funds from USGS	
2011	$37,850	$0	$23,650	$15,800	Install/maintain 1 met station, provide data
2012	$68,850	$0	$43,050	$28,700	Additionally install/maintain 1 wq monitor, provide data
2013	$50,250	$0	$31,400	$20,950	Maintain 1 met station and 1 wq monitor, provide data
Total	$156,950	$0	$98,100	$65,450	

Costs may be reduced by not deploying and maintaining a meteorological station or reducing the time in which it is deployed.

Reports and Products

In addition to accomplishing the four Objectives described in this proposal, a USGS Scientific Investigations Report (SIR) will be produced that would summarize the results of work involved herein. Monitoring and modeling results also would be published on the USGS ORWSC website. Preliminary results would be communicated to all affected agencies (USFWS, JWC, TVID, Clean Water Services) through meetings, emails, and telephone calls.

Report Costs	***Partnering with USFWS***		***Partnering with State/Local Agency***		Subtasks
Federal Fiscal Year	Funds from Collaborator	Funds from USGS	Funds from Collaborator	Funds from USGS	
2012	$17,950	$0	$11,250	$7,500	Data analysis, begin writing report
2013	$58,650	$0	$36,700	$24,450	Finish Report
Total	$76,600	$0	$47,950	$31,950	

Total Budget Estimate

The two budgets below are provided because the costs and any cost sharing depends on the source of the funds. If USGS partners with a local or state agency, we can apply USGS Federal Matching Funds to offset 40% of the total cost.

	Budget Directly with USFWS			Budget with Cooperator, using USGS Federal Matching Funds					
Task	FY 2011	FY 2012	FY 2013	FY 2011		FY 2012		FY 2013	
	Cooperator Funds			Cooperator Funds	USGS Funds	Cooperator Funds	USGS Funds	Cooperator Funds	USGS Funds
1	$26,850	$49,050	$0	$16,800	$11,200	$30,650	$20,450	$0	$0
2	85,500	95,350	46,250	51,300	34,200	58,400	38,950	28,900	19,300
3	0	166,000	177,600	0	0	103,800	69,200	111,050	74,050
4	37,850	68,850	50,250	23,650	15,800	43,050	28,700	31,400	20,950
5	0	17,950	58,650	0	0	11,250	7,500	36,700	24,450
				$91,750	**$61,200**	**$247,150**	**$164,800**	**$208,050**	**$138,750**
Total	**$150,200**	**$397,200**	**$332,750**	**$152,950**		**$411,950**		**$346,800**	

Literature Cited

U.S. Department of Interior, Bureau of Reclamation, Pacific Division, Agrimet, 2011, accessed on 3/12/2011 at [*http://www.usbr.gov/pn/agrimet/10dayarchive.html*]

Dummer, John, 2010, Wapato Lake Pumping – 2010: Clean Water Services, Hillsboro, OR, 6 p.

Tualatin River Flow Management Technical Committee, 2009, Annual Data Report for 2008, Prepared by Bernie Bonn for Clean Water Services in cooperation with: Oregon Water Resources Department, District 18 Watermaster, accessed March 22, 2011 at: [*http://www.co.washington.or.us/Watermaster/SurfaceWater/tualatin-river-flow-technical-committee-annual-report.cfm*]

Tualatin River Flow Management Technical Committee, 2010, Annual Data Report for 2009, Prepared by Bernie Bonn for Clean Water Services in cooperation with: Oregon Water Resources Department, District 18 Watermaster, accessed March 22, 2011 at: [*http://www.co.washington.or.us/Watermaster/SurfaceWater/tualatin-river-flow-technical-committee-annual-report.cfm*]

U.S. Fish and Wildlife, 2007, Tualatin River National Wildlife Refuge Wapato Lake Unit Addition Land Conservation Plan and Environmental Assessment, 104 p, accessed March 22, 2011 at: [*http://www.fws.gov/pacific/planning/main/docs/OR/docswapato.htm*]

U.S. Fish and Wildlife Service, 2010, Tualatin National Wildlife Refuge Planning Update 1—November 2010, accessed March 22, 2011 at: [*http://www.fws.gov/tualatinriver/documents/TualatinPlanningUpdate1web.pdf*]

Wapato Improvement District, 2009, Wapato Lake Water Quality Management Plan for Wapato Improvement District, July 2009, available from Oregon Department of Environmental Quality, accessed March 22, 2011 at: [*http://tualatinriverkeepers.org/files4download/Wapato%20mp%20jul%2009.pdf*]